24. POWDER COATING OVER GALVANIZING

INTRODUCTION
Polyester powder (PE) coatings are thermosetting resins where a low molecular weight polymers and flows during fusion while simultaneously undergoing a chemical conversion to a thermo set or cross linked condition.

Once cured at temperature, the polymer cannot be re-melted to a plastic condition, as is the case with thermoplastic resins like PVC. The use of polyester powder coatings has been well established since the 1960's, and the process is well suited to coating large volumes of uniform products.

Polyester resins have excellent exterior durability in atmospheric environments and are well suited to architectural applications because of their gloss retention, resistance to mechanical damage and resistance to fading.

Reliable application of PE coatings to hot dip galvanized surfaces was identified as a problem by the industry, in plants designed to coat bare steel or pre-galvanized steel products.

In 1987, Industrial Galvanizers undertook a development program with Taubmans (Akzo Nobel) Powder Coating Division to resolve the problems associated with powder coating over hot dip galvanizing. In April 1988. a purpose-designed powder coating plant was commissioned to process hot dip galvanized product using special grades of polyester powder developed by Taubmans.

The facility operated satisfactorily for 16 years until it was decommissioned following a change of ownership.

PROBLEMS & PERFORMANCE
PROBLEMS WITH POWDER COATING OVER HOT DIP GALVANIZING.
There are two significant problems associated with the use of polyester powders on hot dip galvanized products. These are:

- adhesion of the coating to the galvanized surface:
- pinholing of the cured coating.

A lesser problem is related to the curing of the polyester resin that is associated with the nature of the work being processed rather than its coating system.

Adhesion
When steel is hot dip galvanized, it is degreased in a hot caustic bath, pickled in hydrochloric acid to remove oxides, fluxed in a zinc ammonium chloride solution and then galvanized by immersing the work in molten zinc at 455°C.

The zinc reacts with the steel at that temperature to form the galvanized coating, which is typically 80-100 microns in thickness and consists of a series of crystalline zinc-iron alloy layers comprising typically 80% of the coating thickness, coated with a layer of zinc,making up the balance of the coating.

Depending on the metallurgy of the steel and the galvanizing bath conditions, the galvanized coating is sometimes made up entirely of alloy layer with no free zinc layer. These coatings are typically dull gray and tend to be thicker than standard galvanized coatings.

After galvanizing, the work is generally quenched in water containing a low percentage, typically less than 0.25%, of sodium dichromate. The dichromate solution applies a passivation film to the surface of the zinc that inhibits the zinc's reaction with atmospheric moisture prior to the formation of the basic carbonate films that give zinc its outstanding corrosion resistance in atmospheric exposure conditions.

The nature of the basic carbonate films may vary in complexity depending on the environment in which they are formed, but are typically $2ZnCO_2$ $3Zn(OH)_2$.

Weathering in chloride rich marine atmospheres or sulfide rich industrial atmospheres will produce other complex oxides with differing weathering characteristics.

Poor pre-treatment resulted in this total failure of the polyester powder coating in these galvanized posts.

On chromate passivated hot dip galvanized surfaces, there is an added degree of complexity as the chromate film weathers and is progressively replaced by the basic zinc carbonate oxide layer.

When considering the powder coating of hot dip galvanized surfaces, these variables must be considered and minimised to ensure reliable adhesion of the coating.

The most obvious problem experienced when powder coating hot dip galvanized products is pinholing. This occurs when the cured coating is affected by minute bubbles in the paint film that are at unacceptably high density levels and compromise the performance of the coating in service.

While many theories abound, no clear-cut satisfactory explanation has yet been put forward to fully explain this pinholing phenomenon, although plant design and powder chemistry can minimise pinholing effects on galvanized product.

These factors will be discussed later in this paper.

POWDER COATING OVER GALVANIZING PROCESSES
Polyester powder coating over hot dip galvanized surfaces requires a series of processes. These are:

1. Hot dip galvanizing
2. Thermal pre-treatment
3. Chemical pre-treatment
4. Powder application
5. Curing.

Each of these processes is important in assuring the quality of the coating.

CHEMICAL PRE-TREATMENT
Phosphating
Zinc phosphate conversion coatings have been the preferred pre-treatment over hot dip galvanized surfaces producing a fine grained crystalline zinc phosphate at coating weights of 1-2 g/m2. More recently, chrome phosphate has been found to provide superior performance in high-durability applications.

Zinc phosphate has poor detergent cleaning properties, and is not well suited to processing work that is contaminated with organic contaminants.

Iron phosphate is commonly used to pre-treat pre-galvanized products and this is usually applied at iron phosphate concentrations of 0.3-1.0 g/m_2. A number of pre-galvanized products, particularly hollow sections, have a clear polymer coating applied over the galvanized coating by the manufacturer, and this will influence the type of pre-treatment best suited for this type of product.

The zinc phosphate coatings offer superior weathering performance and were found in the development trials to be the only pre-treatment capable of passing 1000 hours salt spray (ASTM B117 -73) and cyclic humidity (BS 3900: Part F2: 1966) tests.

The use of alkaline degreasing operations on galvanized product prior to phosphating must be carefully controlled because of the risk of attack on the zinc by the alkali.

Control of zinc phosphate coating mass is important in achieving good adhesion. With batch pre-treatment processes, extended residence time in the zinc phosphate may result in coating weights exceeding $4g/m_2$. At this coating mass, adhesion problems can arise because of the inherent weakness of the thicker phosphate film.

In continuous process operations, the residence time in the phosphate pre-treatment can be controlled by the line speed, and better control of the phosphate coating is possible. The temperature and concentration of the pre-treatment chemicals can also be modified to match line speed requirements.

With experience, the visual appearance of the galvanized surface after phosphating will give a reliable guide to the presence of a phosphate conversion film of required thickness.

Water rinsing
Following phosphating, the rinsing stages are equally important. All soluble salts must be removed from the surface prior to powder application. Mains water is not necessarily suitable for this application because of its level of soluble impurities.

The two-stage rinse process selected by Industrial Galvanizers included a primary rinse stage followed by a final de-mineralised water rinse.

An additional chromate passivation stage was initially incorporated in the process but coating performance trials revealed that elimination of this stage did not have any measurable effect on coating durability.

THERMAL PRE-TREATMENT
Following phosphating, it is normal procedure to pass the work through a dry-off facility to remove residual moisture from the work prior to powder application. Trials showed that conventional powder coating plant dry-off facilities operated at too low a temperature, and a dry off oven capable of operating at air temperatures of 250°C was found to be desirable, with an optimum operating temperature of 140°C. At surface temperatures over 140°C, the phosphate coating may break down.

Heavier sections with more mass require higher pre-heat oven temperatures to obtain optimum surface temperatures.

POWDER APPLICATION
Polyester powder is applied through electrostatic application guns that operate at voltages from 50 kV to 100 kV. The powder particles acquire an electrostatic charge as they pass through the gun transported by low pressure, dehumidified air at a discharge rate of 100-600 g/min, depending on the application.

The work being coated is earthed and the charged powder particles are attracted to the surface of the work, where they electrostatically adhere in a uniform layer typically 50-100 microns thick. The location and motion of the guns, the transport air pressure and the types of nozzles used will determine the uniformity of distribution of powder.

Complex shapes generally require localised hand spraying to ensure that powder is adequately deposited in all necessary areas on the work.

One benefit of the high temperature pre-heating technology that was developed for the powder coating of hot dip galvanized surfaces has been the improvement in powder uniformity on the surface of the work with a significant minimisation of Faraday Caging effects, which are a problem in recessed areas and that prevent deposition of the charged powder in these areas.

The powder particle size is important in controlling film thickness and ensuring that the electrostatic performance of the powder is maintained.

As up to 40% of powder is recycled, blending powder to maintain optimum size distribution is important. Most commercial powder has a particle size between 2 and 80 microns, with peak distribution in the 40-50 micron range. A mixture of particle sizes is desirable as it aids in establishing a dense, tightly packed particle layer prior to fusion during the curing process.

CURING

Polyester powders are thermosetting resins that cross link at a specific temperature. For these powders to be fully cured, this temperature must be maintained until the reaction is complete. Elevating the curing temperature above the minimum level will shorten the curing time at the risk of burning the powder.

A typical polyester powder will cure in 10 minutes at a metal temperature of 200°C. At 190°C, curing time must be extended to 15 minutes, or may be shortened to 8 minutes at 210°C. These curing parameters will vary between manufacturers, and the process should be tailored to the specific powder requirements recommended by the manufacturer.

Almost all polyester powder coating applications have been developed for manufactured products produced from sheet, wire or other light sections.

The introduction of hot dip galvanized products, which in general are fabricated from heavier sections, requires considerable attention to the curing phase of the process to ensure that the powder is fully cured. It is the surface temperature of the steel that determines the curing of the polyester powder, not the air temperature inside the oven.

Hot dip galvanized products that are powder coated will often contain steel members 12 mm or more in thickness and at normal line speeds of 1.2 m/min, steel surface temperatures will remain well below optimum curing temperatures and the length of the curing oven.

While the coating may appear normal on exiting the oven, it will not have achieved its design properties if the time-at-temperature requirements have not been met. Simple solvent testing procedures will quickly determine whether the coating has been fully cured.

With curing ovens using radiant heaters for curing, care must be taken to ensure that effective curing is being obtained, especially on white or pale coloured coatings which have high reflectivity and may delay heat transfer to the steel substrate.

COATING PERFORMANCE

The coating performance of polyester powder coatings over galvanizing is determined by:

1. The performance of the polymer:
2. The integrity of the application.

POLYMER PERFORMANCE

Polyester powders are available in a variety of grades and their performance is generally reflected in the cost of the powders. The highest grades of powders designed for exterior use have excellent UV resistance and as a result have very good gloss and colour retention in atmospheric exposure conditions. The higher grades of polyester powders can be expected to pass 1000 hour Salt Spray (AS3715 Appendix 2.10), 500 hour Humidity Resistance (AS3615 Section 2.7) and Distilled Water Immersion (BS3900 - F7 at 40"C).

Changes in polyester powder technology have occurred since 1991 because of the potential environmental health problems associated with triglycidyl isocyanurate (TGIC), used as the poly-epoxide curing agent for carboxyl functional polyester powder coatings. Recent opinion as to the health issues associated with TCIG based polyester powders have questioned the validity of the data that led to the move away from TCIG-based powders.

Powder manufacturers developed TGIC free polyester powders and these powders are widely used with acceptable results, although industry sources indicate that TCIG containing powders still provide the best long-term durability.

Polyester powders, while performing well in normal atmospheric exposure conditions, may not perform satisfactorily in chemical environments where epoxy powders may be more appropriate. As a rule, the polyester powders should be considered for high performance architectural applications rather than industrial exposures. Epoxies are unsuitable for architectural applications because of their chalking tendencies when exposed to UV radiation.

There are specialised polymers now available for powder coating applications, with a range of epoxy, acrylic and hybrid powders that are formulated for specific industrial environments.

INTEGRITY OF APPLICATION

Like most applied coatings, failures associated with polyester powder coatings that have otherwise been correctly specified are related to the integrity of application. Apart from the factors discussed above related to quality of application, coating integrity of polyester powder coated galvanized surfaces is most often affected by inadequate powder coverage or pinholing in the cured polyester film.

Problems associated with powder coverage are not unique to galvanized products, but are a function of the design of the product being coated and the techniques and equipment used to apply the powder to ensure adequate penetration of the charged powder particles onto all surfaces of the work.

Pinholing is the most common problem associated with powder coating over galvanizing. It is caused by using incorrect powders and pre-treatment

Pinholing

The phenomenon of pinholing in polyester powders applied over hot dip galvanized surfaces has been identified as the most serious problem associated with coating integrity. To date, no conclusive explanation has been offered as to the specific cause of pinholing on hot dip galvanized work.

Polyester powder manufacturers, along with powder coaters, have combined to develop systems and technology that minimises or eliminates pinholing.
Pinholing can be controlled by:

- pre-heating the work prior to applying powder;
- use of `degassing' grades of polyester powder.

Additives included in the degassing grades of polyester powder delay the onset of fusion of the powder, which gives more time for entrained gas to escape from the molten polymer film.

Superior Coaters uses a batch powder coating system for coating all of INGAL EPS' Estate Poles. On-site garnet blasting facilities and large booths and ovens allow the processing of these larger galvanized poles.

Pinholing of the coating can severely limit its potential performance, especially in aggressive chloride environments where there is often a requirement for architectural steelwork to be used.

The presence of pinholes gives chlorides and other corrodents access to the zinc substrate with consequent production of bulky zinc corrosion products which leach out through both amide (epoxy) and polyester coatings.

While the presence of these corrosion products may not result in associated disbonding of the coating, unsightly white staining of the coating can occur that is quite extensive in relation to the size of the pinholes from which the corrosion products emanate.

Assumptions have been made that the gas causing the pinholing phenomenon arises from within the galvanized coating.
Examination of micrographs of hot dip galvanized coatings make this claim difficult to substantiate.

The typical hot dip galvanized coating comprises a series of zinc-iron alloys that are formed through the reaction of the steel with the zinc at 450°C - 460°C.

These alloy layers take the form of tightly packed crystals in a matrix of free zinc typically around 80 microns in thickness, coated with a free zinc layer that is about 20 microns in thickness.

The metallurgy of the galvanized coating's formation while fully immersed in molten zinc thus makes the absorption of any gases or moisture that would be subsequently expelled from the coating during the 200°C curing of the polyester powder unlikely.

This leaves a gap in fully understanding the performance of polyester powders over hot dip galvanizing that has yet to be filled by the industry. Based on close observation of both hot dip galvanizing and polyester powder coating over galvanizing, the following are suggestions as to causes of pinholing:

a. Hot dip galvanized sections are generally heavier than those typically powder coated. The greater section mass delays uniform fusion of the coating, entrapping air in the lower level of the coating.
b. The thicker phosphate films formed may on the highly reactive hot dip galvanized zinc surface may release water of crystallisation as curing temperatures are approached that give rise to water vapour becoming entrapped in the paint film.
c. The high reflectivity and lower emissivity of the galvanized surface, coupled with the generally heavier section thickness of the steel used delays heat absorption by the steel.

Shiny metal surfaces have the capacity of reflecting as well as absorbing and re-radiating heat. These properties are important in the thermal performance of roofing materials. Uncoated galvanized roof sheeting, for example, has an emittance factor of 0.1 where a dark coloured surface typically has 0.9 emittance.

Elements of each of these factors may contribute to the pinholing phenomenon, and it should be noted that the preheating of the work to higher than normal temperatures prior to powder application would contribute beneficially to reducing the effects of each of these factors.

INGAL Civil Products is a division of Industrial Galvanizers that powder coats all its galvanized Flexfence roadside safety posts with 100% reliability

It is very difficult for any applied coating less than 100 microns in thickness, applied in a single coat, to be free of holidays in the coating. While galvanized substrates supply a high level of corrosion resistance in their own right, and will generate stable corrosion products that will usually seal any pinholes in the coating, the presence of chlorides will result in excessive leaching of the oxides.

For this reason, single-coat polyester coatings are not recommended in marine environments, and two-coat systems are now available that offer exceptional performance where high levels of airborne chlorides are present.

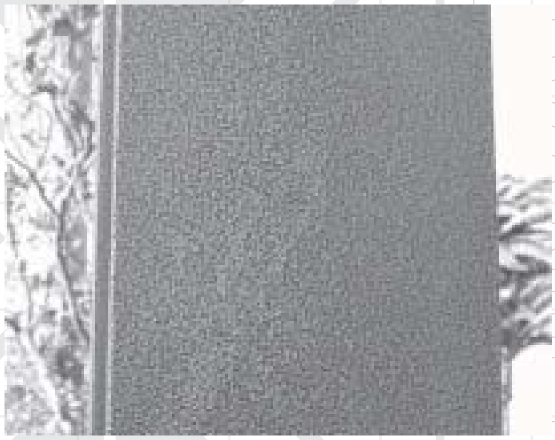
These systems consist of an epoxy based ‘primer’ coat over the hot dip galvanized surface, followed by a polyester top-coat. In addition to providing additional total coating thickness, the additional topcoat reduces the risk of pinholing significantly, although pinholes in the primer coat may give rise to visible defects in the polyester topcoat..

AESTHETICS

In addition to the durability requirements of powder coated hot dip galvanized steel, a major issue is the aesthetic appearance of the finished product.

Hot dip galvanized coatings are inherently less smooth and uniform than continuously applied coatings. Any irregularities in the galvanized coating’s surface will be reflected in the polyester topcoat’s final appearance, particularly with high gloss products.

Ripple-finish powders have now been developed that provide an attractive finish while masking the irregularities that are typical of hot dip galvanized coatings.



Hot dip galvanized surfaces are rarely smooth and uniform. The use of hammertone or ripple powders conceal surface irregularities and produce an attractive and durable finish

SCHEDULING

Many products that are hot dip galvanized are not series production items. Many may be one-off products that are required to be a specific colour. No heavy-duty or architectural painting technology is as efficient as powder coating for processing large number of similar products in long runs of the same colour.

This benefit can rarely be realised with hot dip galvanized products. This can create scheduling issues for powder coaters as colour changing is a significant operation that requires complete and thorough cleaning of the powder delivery systems.

Powder coating companies such as Superior Coaters in Queensland has addressed this issue by taking a completely different approach to the continuous conveyor handling systems typical of most powder coating operations.

Superior Coaters has a facility specifically designed for processing structural and heavier fabricated components. The Superior Coaters plant has a large garnet-blasting chamber in the facility. This removes one of the major hurdles in the galvanizing process, as the surface condition (passivated, un-passivated, weathered, oxidized) becomes irrelevant. All work is whip blasted in the garnet chamber immediately prior to powder application, ensuring a clean zinc surface.

The powder is applied electrostatically in a spray-to-waste booth and the work is then transferred to one of two large batch-curing ovens. Superior Coaters have oven management systems that ensure that the powder is correctly cured on whatever steel section to which it has been applied as the steel temperature, and not the oven atmosphere temperature determines the curing time..

This system has been used successfully on a number of ongoing INGAL EPS (Industrial Galvanizers Pole Division) for a number of years and has produced a superior coating outcome for INGAL EPS who previously used wet paint systems on its period contract pole products.

The batch treatment system such as that used by Superior Coaters allows easier `degassing' of hot dip galvanized items using high temperature preheating. Degassing grades of powders are only available in a limited colour range, and this required the products top be thermally degassed for about 50% of the work processed by Superior Coaters.

CONCLUSION

Polyester powder coating of hot dip galvanized surfaces can be accomplished successfully with proper process and quality controls. There is an opportunity to extend the application of polyester powders to heavier steel sections and fabrications with the attendant cost and performance benefits of powder coatings.

INGAL
SPECIFIERS MANUAL

01 - SPECIFIERS MANUAL — THIRD EDITION

Industrial Galvanizers Australian Galvanizing Division (IGAG) operates nine galvanizing plants around Australia, ranging in size from large structural galvanizing facilities to specialised small plants designed to process small parts.

The Australian Galvanizing Division has galvanized in excess of 2 million tonnes of steel products in Australia since its first plant was commissioned in 1965 and is recognized for its ability to handle complex and difficult projects, as well as routine contracts.

This experience has been collated in the Specifiers Design Manual, to assist those involved in the design of steel products and projects to better understanding the galvanizing process and allow the most durable and cost-effective solutions to be delivered to these products and projects. All sections of this Third Edition have been completely updated and additional sections have been included to provide additional technical information related to the use of hot dip galvanized steel.

In addition to its Australian Galvanizing operations, Industrial Galvanizers Corporation has a network of manufacturing operations in Australia, as well as galvanizing and manufacturing businesses throughout Asia and in the USA.

The company's staff in all these locations will be pleased to assist with advice on design and performance of hot dip galvanized coatings and products. Contact details for each of these locations are located elsewhere in this manual.

This edition of the Industrial Galvanizers Specifiers Manual has been produced in both html and .pdf formats for ease of access and distribution and all documents in the Manual are in .pdf format and can be printed if paper documents are required.

The Specifiers Manual is also accessible in its entirety on the company's web site at www.ingal.com.au.

Additional copies of the Specifiers Manual are available on CD on request.

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